Newsletter

FALL 2023

SURFACE

Surface imaging, analysis & metrology news from Digital Surf

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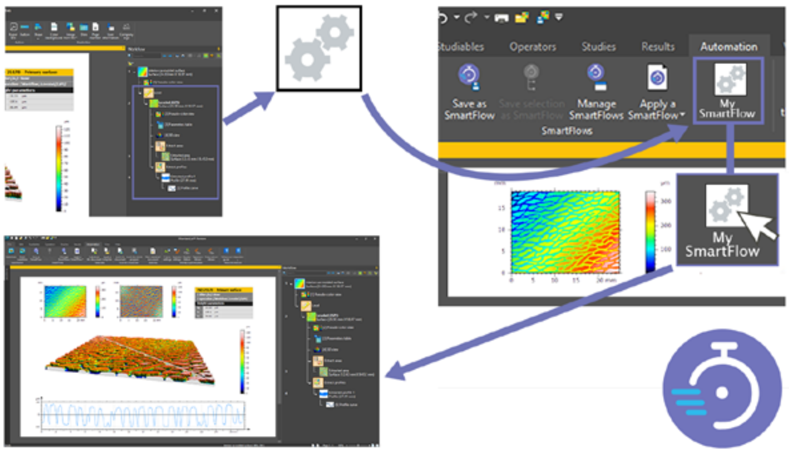
IN THIS ISSUE

MOUNTAINS® 10.1 DISCOVER SMARTFLOWS (AND HOW THEY MAKE YOUR ANALYSIS EVEN FASTER)



A new version of industry's go-to surface and image analysis software has just been released and will be on show at MRS Fall in Boston (USA) at the end of this month.

This release includes the update of SmartFlows (formerly known as Minidocs), a key tool for automating data analysis. Batch processing has never been better, no need to write code, just select your favorite sequences and turn them into a SmartFlow in only a few clicks!

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Meet our **EXPERTS**

When you're dealing with complex image and surface analysis, nothing beats the advice of an expert!

Our teams of metrology & microscopy analysis specialists regularly participate at conferences and exhibits the world over.

Find out where you can run into them next: www.digitalsurf.com/events

READY FOR MOUNTAINS® 10.1? ALL THE NEW FEATURES AVAILABLE THIS FALL

A brand new version of industry's go-to surface and image analysis software has just been released and will be on show at the **Materials Research Society Fall meeting & exhibit** in Boston, Massachusetts (USA) at the end of November. This latest release sees the update of SmartFlows (formerly known as Minidocs), a key tool for automating data analysis, the enhancement of the ever-popular Particle Analysis tool and many new options for users analyzing spectra from techniques such as Raman or IR. Read on to find out more.

WHAT'S IN YOUR SMARTFLOW?

A SmartFlow (previously called Minidoc) is an analysis sequence that you can save and reapply to other datasets quickly and easily, saving you precious time.

It's batch analysis at its best, no need to write code, just select your favorite sequences and turn them into a SmartFlow in a few clicks.

Your SmartFlows will appear in the ribbon, allowing you to reapply them as quickly and easily as they were created.

Mountains® 10.1 sees notable interface improvements and smoother usability: the SmartFlow interface has been reorganized and improved. It is also now possible to apply SmartFlows to several studiables at the same time.

- **WATCH THE VIDEO: bit.ly/3SPvefx**
- **TELL US WHAT'S IN YOUR SMARTFLOW AND WIN A PRIZE: bit.ly/3MBtKl8**

PARTICLE ANALYSIS TOOL ENHANCED

The popular Mountains® Particle Analysis tool allows users to detect and quantify structures of any size or shape in profilometry or microscopy data.

In version 10.1, further improvements have been made to make life even easier for users studying this kind of data:

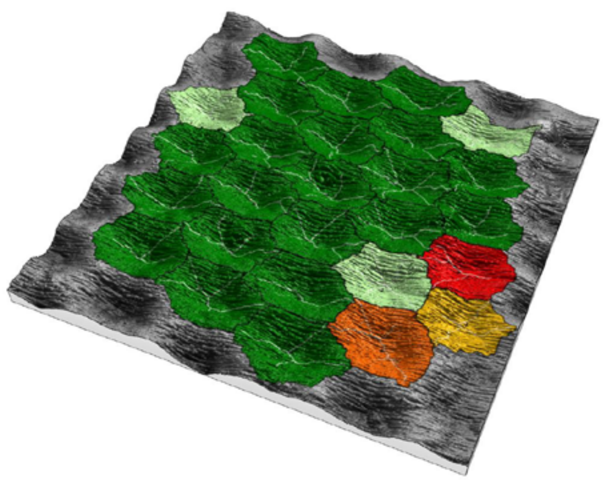
- The contextual ribbon has been reorganized
- Choosing detection and calculation channels has been made more intuitive
- Particle classification has been improved (group classes by parameter).

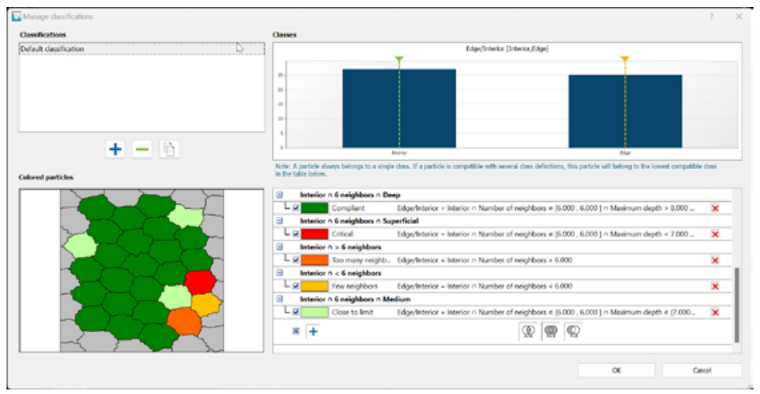
COMPREHENSIVE TOOLBOX FOR ANALYSIS OF SPECTRA

Version 10.1 sees the coming of age for analysis of spectra from a variety of techniques (Raman, IR etc.) Extensive new developments now put a comprehensive set of tools at the fingertips of users working with this kind of data. In particular:

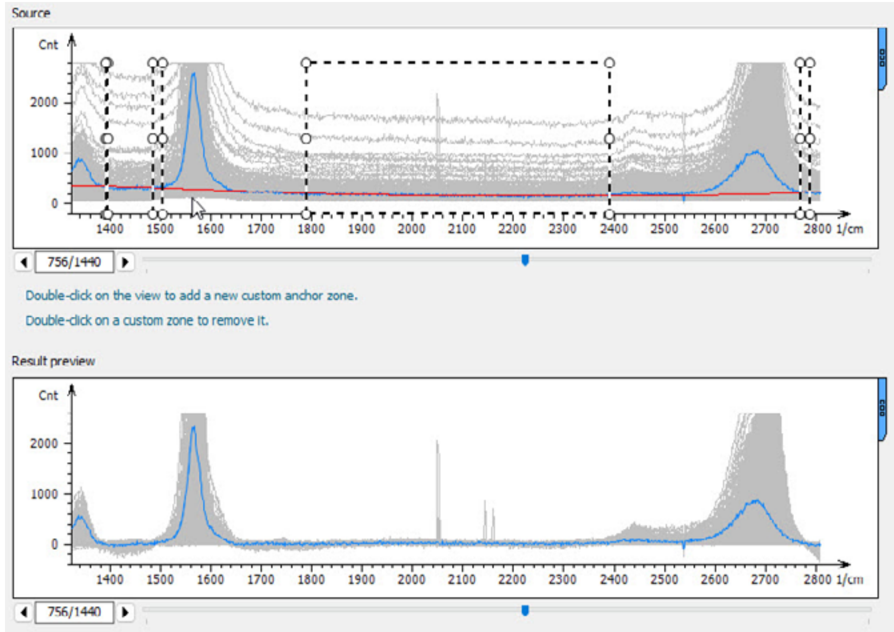
- **Visualization of spectra** has been enhanced with Z-axis management in hyperspectral image view and a bigger, more visible cursor
- The **Correct the baseline** operator has been improved with the addition of anchor zones, lines, second order polynomials
- Users can now **Remove spikes** (cosmic rays) from spectra ensuring clean data before proceeding to analysis
- **Extracting non-rectangular areas** (circular or custom) of hyperspectral images is now possible.

In addition, a new **Use spectral bands** operator provides users with an alternative method for creating spectral maps from hyperspectral images.





Above. *In version 10.1, further improvements have been made to make life even easier for users analyzing particles including better readability in the particle classification dialog.*



Above. *Correcting the baseline (in red) on Raman spectra using custom anchor zones.*

NEW FEATURES FOR SPM

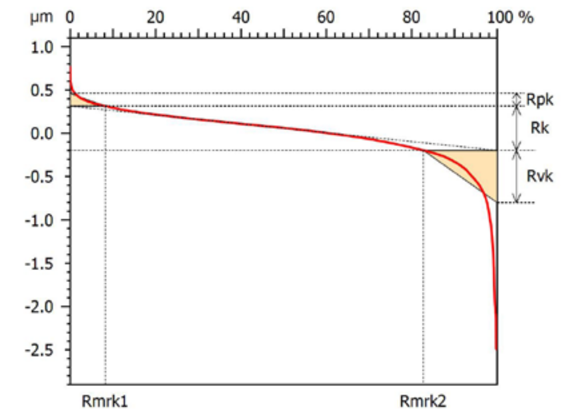
Traditionally, fall versions always have something in store for the scanning probe microscopy (SPM) community and 10.1 is no exception.

- A new operator in the FFT toolbox allows users to **filter surfaces profile by profile** by removing wavelengths (1D FFT filtering). This can be useful for reducing scanning noise due to mechanical vibrations or light pollution for example.
- A new advanced **manual method for indentation analysis** is also available.

IMPROVEMENTS FOR PROFILOMETRY

Last but not least, many improvements and enhancements await those studying profiles and surfaces.

- **Rk parameters & default filters** have been updated in accordance with ISO 21920-2.
- **Z-scale range** can now be imposed in Rk and Sk studies.
- **Remove form** and **Extract surfaces** are now available on series of surfaces.
- **Thresholds in the Volume parameters study** can now be calculated automatically allowing better automation of this kind of analysis.



Information	
Filter settings	Robust Gaussian filter, 0.8 mm,...
Standard	ISO 21920-2

Parameters	Value	Unit
Rk	0.5112	µm
Rpk	0.1472	µm
Rvk	0.6036	µm
Rmrk1	8.218	%
Rmrk2	82.70	%

Above. *Renamed Rk parameters & default robust Gaussian filter from ISO 21920-2.*

LEARN MORE & UPDATE

Check www.digitalsurf.com for full details of the v10.1 release (available Nov 2023). Access to the new version is included for users with an active **Mountains® Software Maintenance Plan**. To find out more about your Maintenance options, please contact sales@digitalsurf.com

ANALYZING SILICON STRAIN WITH RAMAN SPECTROSCOPY

By Renata Lewandowska, product manager for spectral applications at Digital Surf

WHAT IS STRAIN ANALYSIS?

Strain in semiconductor devices is a vast and important subject. Instinctively, one could be tempted to think of strain as a sort of mechanical failure - think cracks when the strain is too high - but strain can also be used to influence the electronic properties of semi-conductors, and is used as so in **strain engineering** [1, 2, 3, 4, 5].

Raman spectroscopy is an ideal technique for measuring strain, as it is sensitive to even very small changes in the crystalline lattice. It also offers high spatial resolution for the precise analysis of electronics elements, down to a few hundred nanometers using classic Raman and a few nanometers in TERS (tip-enhanced Raman spectroscopy).

Generally speaking, strain analysis can be quite complex. Strain is the result in materials of applied stress (which can be deformation, lattice mismatch or doping, for example). Depending on the direction of the stress with respect to the crystalline structure of the material, strain can propagate differently. A very comprehensive explanation of this subject is given in an excellent article by Ingrid De Wolf [6].

EXAMPLE OF ANALYSIS OF A SILICON CHIP

In this example, we analyzed **strain measurements made on a silicon chip** using Raman spectroscopy. The metal part induces the mechanical strain in the silicon in the vicinity of the interface.

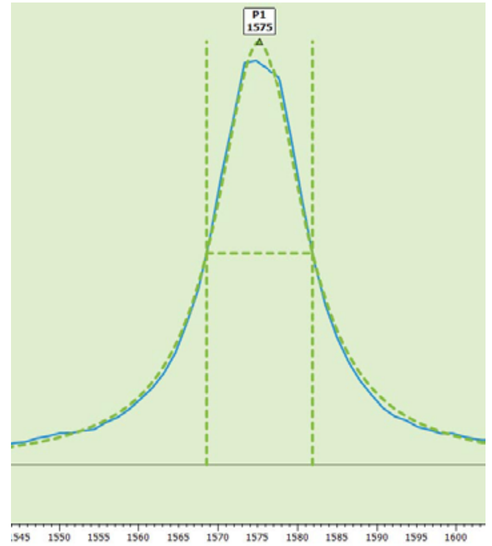
To simplify this analysis, we will suppose here that strain is uniaxial [6]. The relation between stress σ and peak shift Δω is linear and described as [6,7]:

$$\sigma[MPa] = -500 \times \Delta\omega[cm^{-1}]$$

The peak shift to higher wavenumbers means the sample is under compressive stress and the peak shift to lower wavenumbers indicates tensile stress.

PEAK FITTING

To analyze peak shift due to strain, peak fitting is used. Peak fitting uses mathematical functions, mainly Gaussian or Lorentzian in spectroscopy, to describe in a consistent way a real – measured – peak with parameters such as peak position, peak width or peak area. In the picture below, the blue line corresponds to a measured spectrum and the green line corresponds to the fitting function.



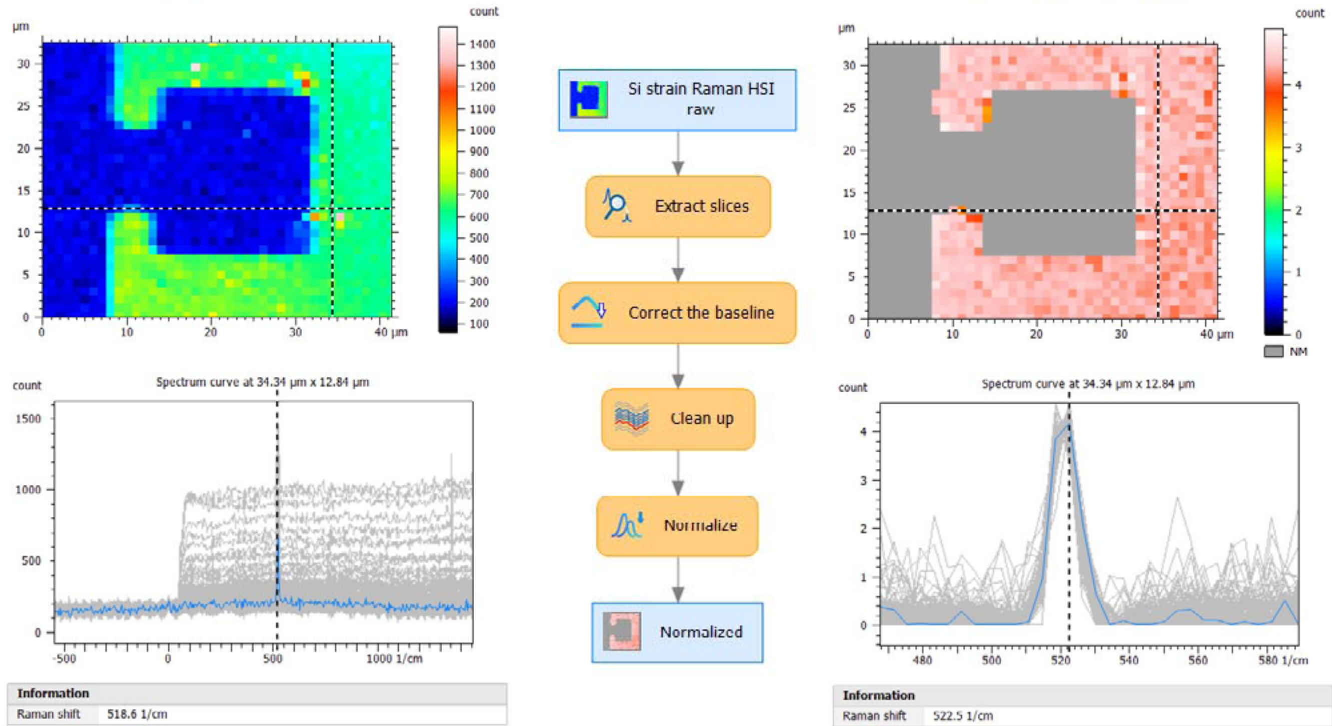
DATA PRE-PROCESSING

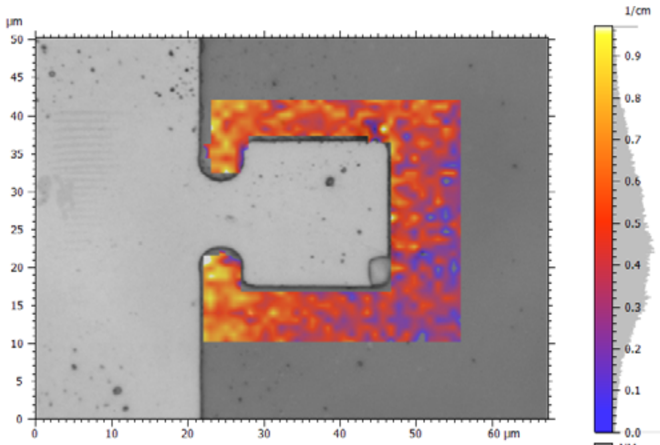
Data visualization and **pre-processing** are two preliminary steps necessary for correct analysis. In MountainsSpectral® the Hyperspectral image view allows versatile visualization of spectral data with a large choice of display options in order to obtain all the information necessary to determine pre-processing steps.

In this case, the following pre-processing steps were chosen to prepare the data for analysis:

1. Reducing the spectral region of analysis around of the peak of interest (**Extract slices** operator)
2. Bringing all the spectra to the baseline = 0 (**Correct the baseline** operator)
3. Removing spectra taken on the metal part, which doesn't contain any Raman information (**Clean up** or **Extract area** operator)
4. Removing the effect of the tilted surface (**Normalize** operator)

Obviously, these steps should always be adapted to the data and to the analysis which will follow.





Top. *Pre-processing steps applied to spectral data.*
Bottom. *Optical microscopy image of the silicon chip studied overlaid with peak shift parameter map.*

DATA ANALYSIS

The **Peak fitting** study and **Parameter map** operator were used to perform the peak fitting and to visualize results.

We will focus here on the image directly above which represents the distribution of the peak shift of the peak of interest from its ideal non-strained position which is 520.7 cm⁻¹. We can see that, close to the metal pin, the silicon is strained because the peak shift is about 1 cm⁻¹. As the peak position shifts to higher values, it indicates compressive strain. At a certain distance from the metallic pin, the shift peak values become closer to 0, which demonstrates relaxation (no strain) of the silicon.

REFERENCES

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[7] G. Sarau et al., "From Micro– to Macro–Raman Spectroscopy: Solar Silicon for a Case Study" in "Advanced Aspects of Spectroscopy", InTech, 2012 DOI: 10.5772/2757, www.intechopen.com/chapters/38553

QUANTITATIVE MAPPING OF MECHANICAL AND VISCOELASTIC PROPERTIES AT THE NANOSCALE

In the last few years, the use of SPM techniques in many areas of research has greatly increased. **Professor Philippe Leclere, director of the Laboratory for Physics of Nanomaterials and Energy (LPNE) at the University of Mons (UMONS)** in Belgium, within the Research Institute for Materials Science and Engineering, has been studying the impact of this increase and describes for *Surface Newsletter* how his team is addressing the challenge of analyzing and mapping large quantities of data on material properties at the nanoscale.

Scanning Probe Microscopy (SPM) is one of the main tools responsible for the emergence of **novel soft functional materials** and for the **characterization** of their physical properties at the nanoscale.

BIG DATA ISSUES IN SPM

At the **Laboratory for Physics of Nanomaterials and Energy (LPNE)**, SPM helps us to solve various challenges we face with materials in the fields of energy harvesting, organic electronics, biosensors, self-assembly, biotechnology, life sciences, and nanomedicine to name but a few.

The number of advanced SPM techniques commercially available these days keeps growing at an extremely fast rate and this generates a huge amount of data.

The quantitative mapping of the actual mechanical properties of materials at the nanoscale constitutes a real challenge for professionals.

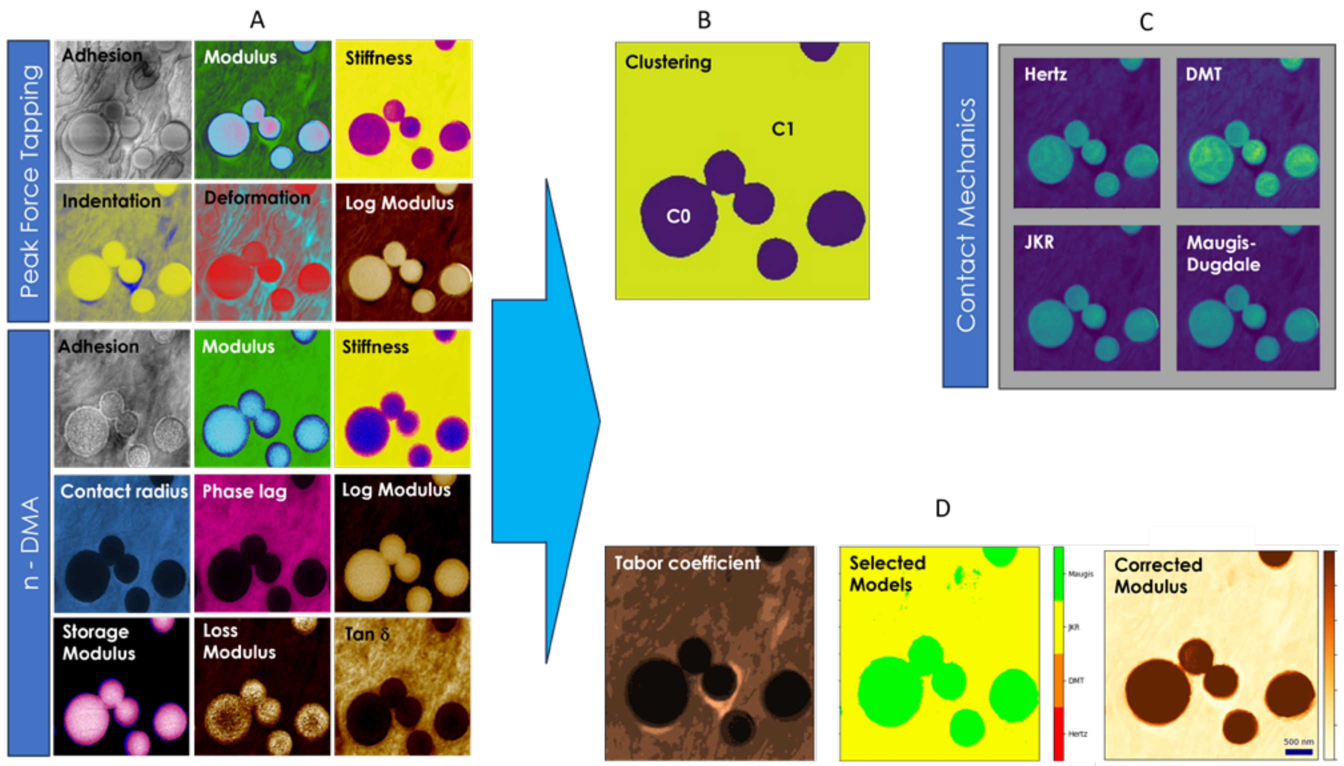


*Figure 1. Andy Warhol-like representation of the data analysis of PS-PCL polymer blend. **Panel A.** Each image represents one of the observables (or material properties) obtained by PFT or n-DMA. **Panel B.** Results of the data clustering (here k = 2). **Panel C.** Rigidity modulus map calculations depending on the contact mechanics model used. **Panel D.** Calculated Tabor coefficient map, the selected model and the re-mapping of the rigidity modulus according to the most appropriate model.*

The number of collected observables is also rapidly increasing and machine learning processes are now mature enough to analyze data user-independently. Most of the existing imaging modes proposed by the manufacturers take into account one of the contact mechanical models (among the few analytically available) for the entire acquisition.

RECALCULATING RIGIDITY MODULUS ON PS-PCL

In this growing field of research, the contribution of the LPNE mainly consists of **data clustering and mapping of material properties** using the most appropriate contact mechanics model for each pixel based on the approach–retract force curve analysis.

We were able to recalculate the mechanical properties such as the **rigidity modulus** with the aim of importing all these channels into MountainsSPIP® software for deeper analysis, particularly statistical analysis, and to benefit from the software's rendering capacities.

Figure 1 illustrates the capabilities of this approach on a **polymer blend made of polystyrene (30%) and polycaprolactone (70%)** using Peak Force Tapping (PFT) and nano Dynamic Mechanical Analysis (n-DMA) techniques. The polystyrene (PS) forms circular-shaped objects within the semi-crystalline matrix of the polycaprolactone (PCL).

This process has been extended with success to many other materials including nanocomposites, hydrogels, block copolymers, cosmetics and bacteria.

For the data clustering process, it is important to emphasize that any channel corresponding to electrical, magnetic, thermal or piezoelectrical properties can be considered as an input observable, thus extending the analysis to any material property.

For this purpose, we used Principal Component Analysis, K-Means or Gaussian Mixed Model algorithms.

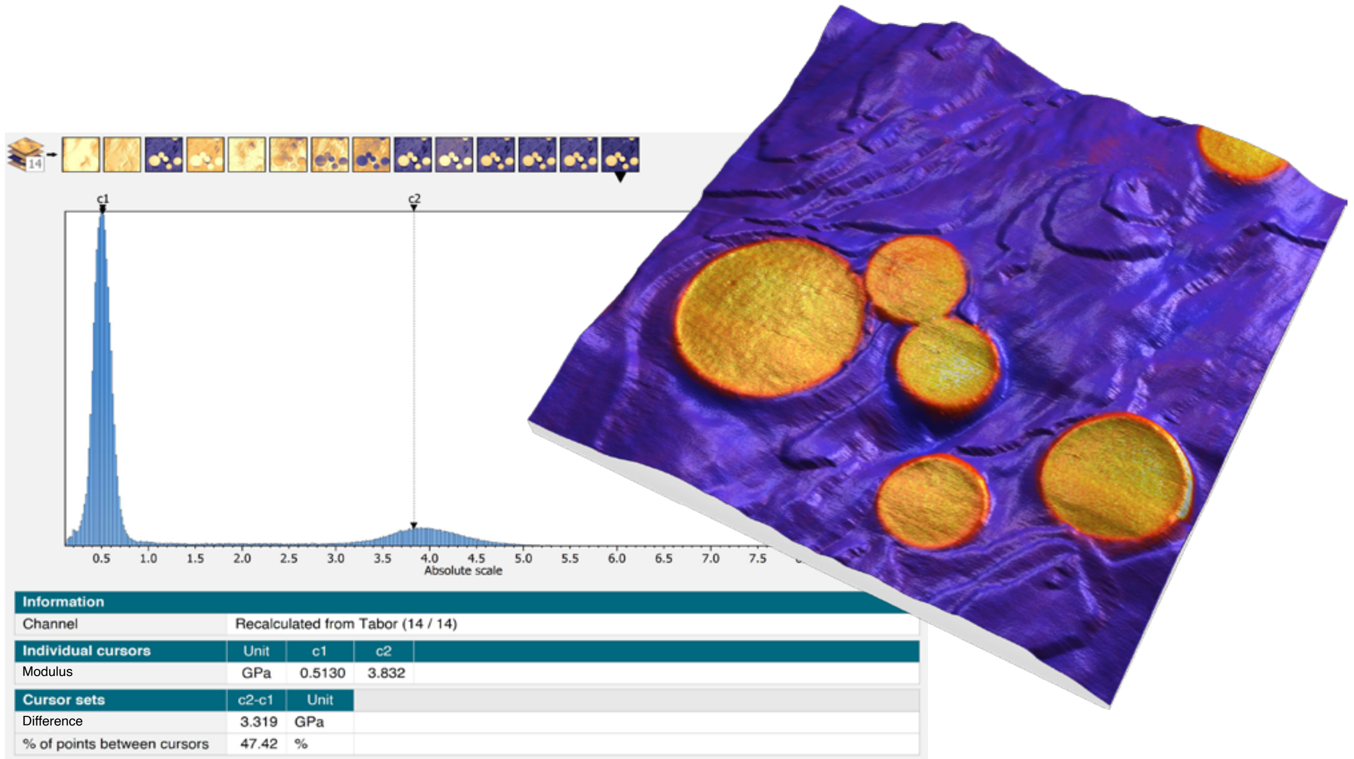


***Figure 2.** Recalculated rigidity modulus histogram (left) and 3D visualization of the recalculated modulus overlaid on a the corresponding topography channel (right).*

CONTACT

Professor Philippe Leclere - philippe.leclere@umons.ac.be - @LpneUmons

INSTRUMENTS & SOFTWARE USED

Scanning probe microscope (Bruker Dimension Icon) and MountainsSPIP® 10 software.

WHAT IS SPECTRAL ANALYSIS?

In the world of precision engineering and quality control, the art of surface metrology plays a pivotal role. One powerful tool in the surface metrologist's arsenal is **spectral analysis**, a technique that enables us to delve into the complexities of surface topography with great precision. In this article **François Blateyron,** senior surface metrology expert at Digital Surf, discusses spectral analysis and why it is key to understanding surface texture analysis.

BASICS OF SIGNAL PROCESSING

Performing spectral analysis on a signal means examining its content in terms of frequencies (or wavelengths).

The simplest signal is a sine wave, which is defined by its wavelength, amplitude and phase. Wavelength defines the length of an oscillation in the spatial domain (it is given in µm, nm or any length unit). If this wave propagates at a particular speed (for example a value ν in m/s) then you can define its frequency $f=\nu/\lambda$ which is proportional to the inverse of the wavelength λ.

In surface texture, signals represent profiles or surfaces, so it is convenient to use wavelengths instead of frequencies, as signals are in the spatial domain.

SPECTRAL CONTENT ANALYSIS

To switch from the spatial domain to the spectral domain, or vice-versa, we use a **Fourier transform**, usually via an FFT algorithm which is fast and optimized.

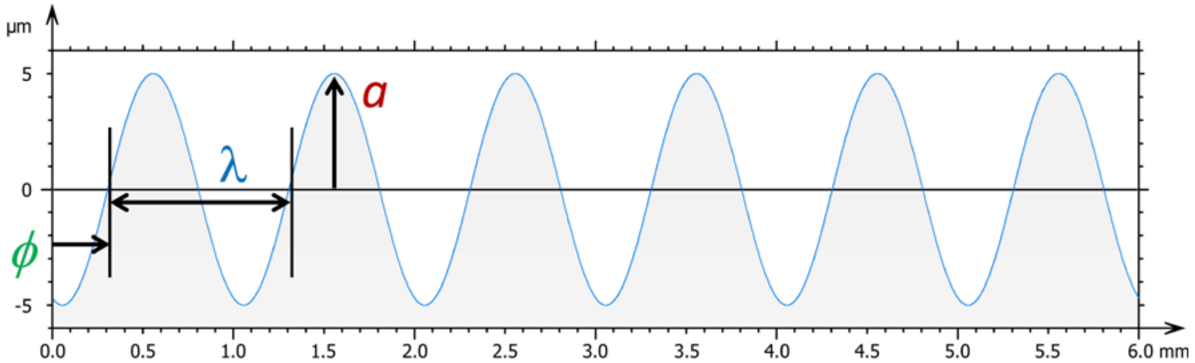
The spatial description of a profile or surface, or its spectrum, are two different ways to describe the same object. They are dual representations.

The usual representation of a spectrum is either a 1D graph that represents amplitudes in function of the frequency index, for a profile, or an image that represents amplitudes in color, in function of the X/Y indices of the 2D spectrum.

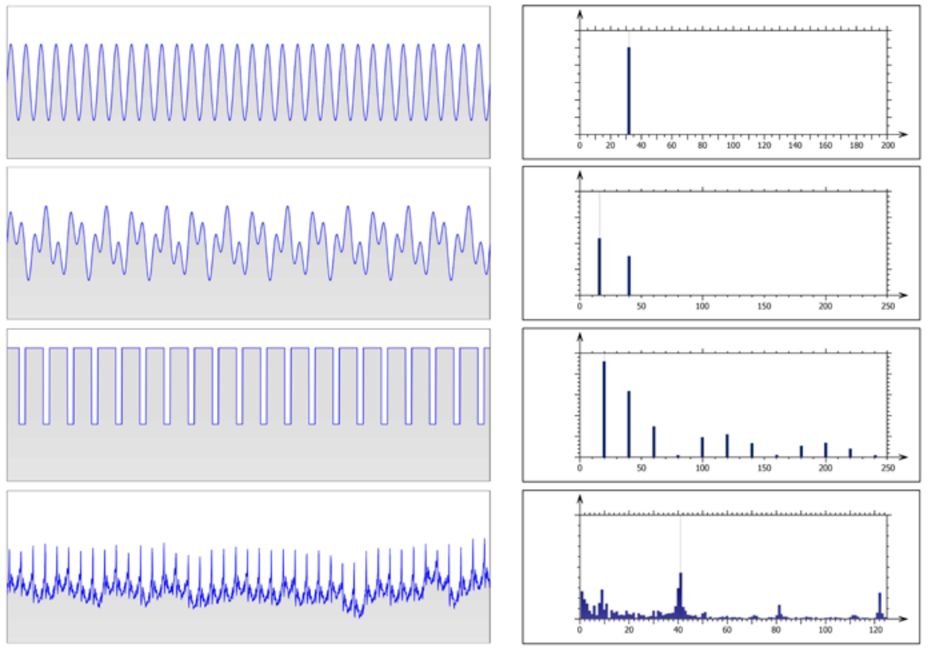
By looking at the spectrum of a signal, it is possible to identify periodic waves, as they appear as peaks on a 1D spectrum or white pixels on a 2D spectrum.

Peaks can represent actual structures on the surface, such as the periods of a periodical material measure, or they can be spurious oscillations that may come from vibrations or electrical frequency leaking due to the power supply (50 or 60 Hz).

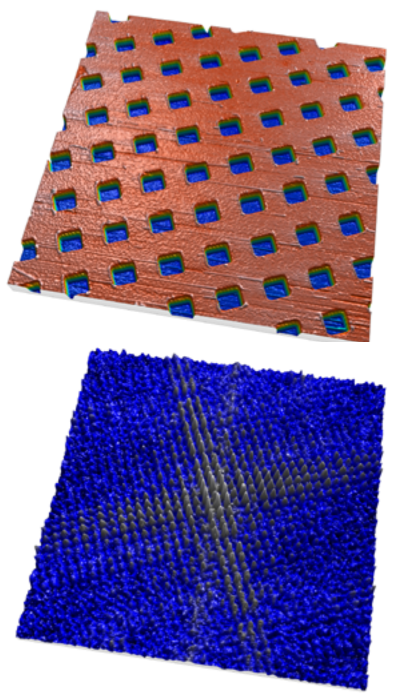
The figure on the opposite page shows several profiles and their corresponding spectrum. The spectrum of a perfectly sinusoidal wave will, by definition, consist of a single spectral ray, since its Fourier series decomposition only has one term. A signal composed of two sinusoids at different frequencies and amplitudes will show a spectrum consisting of two spectral rays. A slightly more complex signal, such as a periodic square with a non-symmetrical duty cycle, gives a spectrum consisting of the main harmonic and complementary harmonics, all of which are multiples of the main frequency.



Above. *The three parameters that define a sine wave: amplitude a, wavelength λ, phase ϕ.*



Above left. *Several profile shapes.* **Right.** *Their corresponding spectrum.*



Above top. *A surface.* **Bottom.** *Its corresponding spectrum.*

Finally, in the case of a real periodic profile, which contains irregularities, we find the main frequency and its harmonics, but also other smaller rays around it, which represent the irregularities of the profile.

FILTRATION

The aim of a filter is to attenuate part of the spectrum and transmit the other part. For example, by attenuating long wavelengths in a primary profile, above a cut-off value (λc or Nic), we obtain the roughness profile. It is then an L-filter (or a high-pass filter). A microroughness filter that removes the shortest wavelengths below λs (or Nis) is a S-filter.

Different filters (Gaussian, Spline, Robust Gaussian) have different frequency response curves but are all based on the same principles and the same actions on the spectrum. These filters are described in the standard series ISO 16610.

SOFTWARE TOOLS FOR SPECTRAL ANALYSIS

In Mountains® software, several operators and studies allow the analysis or modification of the spectrum. The **Filter the spectrum** operator allows the user to interactively remove spectral content from the spectrum. The **Threshold the spectrum** operator is an easy way to reduce noise by removing spurious frequencies.

The **Frequency spectrum** study displays the spectrum with a cursor to check the amplitude and phase of a particular spectral peak. The **Averaged Power Spectrum Density** study provides a better look at long wavelengths, and has a mode for evaluating the PSD for optical applications. Many other features are also available.

=> LEARN MORE: www.digitalsurf.com/software-solutions/profilometry/

ADDITIONAL RESOURCES

- *A recent video in the Surface Metrology Guide explains the basics of filtration and spectral analysis: www.youtube.com/watch?v=2OMrfNUt0T4*
- *"Filtration techniques for surface texture" article describing the differences and use cases of different filters: guide.digitalsurf.com/en/guide-filtration-techniques.html*
- *A special filter combination is the band-pass filter, which is described in the following article: guide.digitalsurf.com/en/guide-bandpass-filters.html*

A LOOK BACK AT ANOTHER BUSY SUMMER SEASON

M&M

This year, the **Microscopy & Microanalysis meeting** was held in Minneapolis, MN, late July. Organized by the Microscopy Society of America, the M&M meeting was the opportunity to learn more about the latest trends in the electron microscopy market. The Digital Surf team was on hand to welcome visitors to our booth and provide them with live demos of Mountains® 10 features dedicated to microscopy image analysis.

***Above.** Anne, Nicolas & Cyrille at M&M 2023.*

JASIS

We were pleased to be exhibiting at the **JASIS trade show** this year again. Known as one of the largest exhibitions in Asia for analytical and scientific instruments, JASIS took place from September 6 to 8 at Makuhari Messe in Tokyo, Japan.

Arnaud, Damien and our valued interpreter Sato-san were present to welcome visitors to our booth and discuss their applications in the fields of scanning probe microscopy, scanning electron microscopy and spectroscopy.

***Above.** The Digital Surf booth at JASIS 2023.*

SciX

The Digital Surf team then attended the **SciX conference** in Sparks, Nevada (USA), from October 9 to 11. The Digital Surf experts for spectral analysis were thrilled to take part in the "Great Scientific Exchange". It was the opportunity to meet scientists from around the world and showcase MountainsSpectral® features dedicated to spectral & correlative analysis.

***Above.** The Digital Surf team at SciX 2023.*

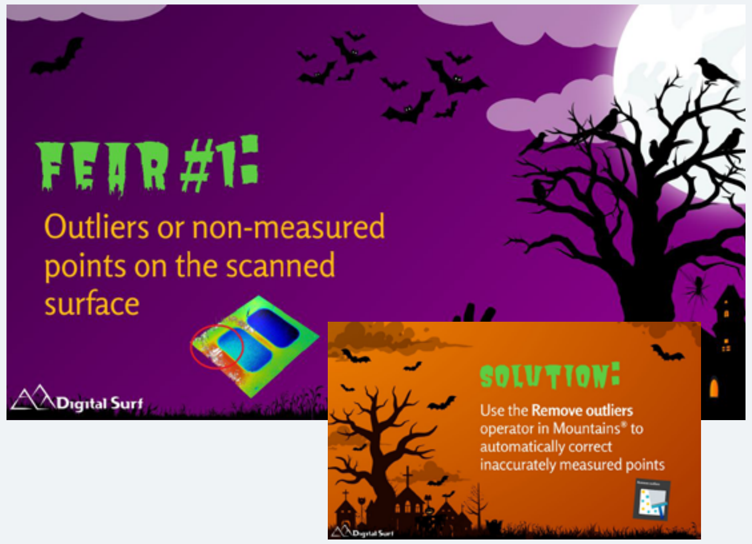
MOUNTAINS® WEBINARS

Visit our webinar platform to learn more about the new features included in version 10 of Mountains® software: Fiber Analysis, Raman spectroscopy data analysis, etc.

A new webinar series dedicated to **Particle Analysis** and new v10.1 improvements will be broadcast in December & January, stay tuned!

All our webinars are available to watch on-demand free of charge on our channel: www.digitalsurf.com/learning/webinars/

WHAT'S HOT ONLINE



LOVED ON LINKEDIN

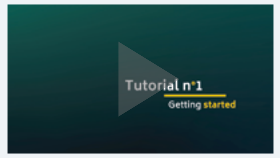
In the spirit of Halloween, we recently shared the biggest & spookiest fears of metrologists & microscopists out there coupled with a few solutions.

Check them all out: bit.ly/3FNkbLU

SPOTTED ON FACEBOOK

We recently learned what the mighty T-rex really ate thanks to the latest findings published by researcher Mugino Kubo & team. Want to find out more? [bit.ly/3QG1EY6](bit.ly/3QG1EY6)

Have you been to our YouTube channel?



We have lots of quick helpful videos, as well as tutorials on Mountains® software basic and advanced features, check them out: [bit.ly/2U2I2za](bit.ly/2U2I2za)

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and learn about characterizing surface texture in 2D and 3D
www.digitalsurf.com/guide

CATCH UP WITH US

Materials Research Society (MRS) meeting & exhibit
Nov 28-30, 2023 | Boston, Massachusetts, USA

Pittcon | February 26-28, 2024 | San Diego, California, USA

European meeting on Infrared NanoSpectro-Imaging
March 13-15, 2023 | Paris, France

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